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ORIGINAL RESEARCH

Response of Various Cultivars of Cucumber to Different Isolates of *Pseudoperonospora cubensis* (Berk et Curt.) Rostow Under Artificial Epiphytotic Conditions

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ABSTRACT: This study was conducted in the Department of Plant Pathology, University of Agriculture, Peshawar, during the 2011 growing season to assess the response of various cucumber cultivars to different isolates of the downy mildew pathogen *Pseudoperonospora cubensis* under artificial epiphytotic conditions. Five cucumber cultivars (Desi, Long Green, F1 Hybrid, Dollar, and Khyber) were evaluated for their susceptibility to four distinct isolates of P. cubensis. Statistical analysis revealed significant differences ($p < 0.05$) among cultivars, isolates, and their interactions compared with the control treatment. The F1 Hybrid and Dollar F1 cultivars exhibited the lowest disease severity, whereas isolate 4 induced the highest level of infection. In contrast, control plants demonstrated comparatively lower disease severity. The interaction between cultivars and pathogen isolates remained significant at both 30 and 40 days after inoculation, indicating differential host-pathogen responses under controlled conditions..

KEYWORDS: Cucumber cultivars, downy mildew, *Pseudoperonospora cubensis, i*solates.

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1. Introduction

Cucumber *(Cucumis sativus L.)* is the fourth most widely grown vegetable crop (Tatlioglu, 1993) in the world after tomato (*Lycopersicon esculentum* Mill.), cabbage *(Brassica oleracea var. capitata L.)* and onion *(Allium cepa L.)*. Species of the Cucurbitaceae family are grown widely around the world as crops. The family is comprised of about 118 genera and 825 species that are primarily annual vines (Jeffrey, 1990). The genus *Cucumis* contains 52 species, of which *C. sativus* and *C. melo* are the two most economically significant (Ghebretinsae et al., 2007). In Pakistan, cucumbers are grown on 1,274 hectares producing 5,539 tonnes of fruits (MINFAL, 2008).

Cucurbit downy mildew is distributed widely worldwide (Palti and Cohen, 1980) and is one of the most destructive pathogens of cucurbits. It is the most important disease of cucumber, causing more than 50 % losses. The downy mildew influencing factors are environment and host. This disease has been reported from 70 countries, with the most severe outbreaks occurring in humid regions. Environmental conditions play a fundamental role in disease intensity (Cohen, 1977). Leaf

wetness is critical for the disease to progress; if free moisture is not on the leaf, sporangia will not germinate. Adequate leaf moisture is provided by rainfall, dew or irrigation. Ideal temperature for infection is 15° C (Thomas, 1977).

In cucumber, symptoms of downy mildew occur on the leaf blades. Infection first appears as small, water-soaked lesions on the underside of leaves, the lesions turn chlorotic and dark-colored spores form on the underside of the leaf. Chlorotic spots turn necrotic. Eventually, the entire leaf will become necrotic and die (Palti and Cohen, 1980; Chen et al., 2020). Downy mildew symptoms on cucumber will vary depending on its level of resistance (Shirley et al., 2022). The most resistant cucumber cultivars exhibited a hypersensitive response with small necrotic or chlorotic spots and limited sporulation (Chakraborty et al., 2022). The most susceptible will show many large chlorotic and necrotic lesions with abundant sporulation.

Studies on the host range of *P. cubensis* indicated that approximately 20 genera, including 50 species in the Cucurbitaceae, were there hosts. A total of 19 host species are in the genus *Cucumis* (Palti and Cohen, 1980; Lebeda, 1992a, and Lebeda and Widrlechner, 2003). In addition to cucumber, other economically important hosts of *P. cubensis* are melon (*Cucumis melo* L.), watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai and squash (*Cucurbita* spp.) (Whitaker and Davis, 1962).

There are several strategies to manage the disease. These include cultural, chemical and planting resistant or tolerant varieties. Several fungicides have been found effective against the disease. These includes Alliette, Chlorothalonil and Ridomil gold (Sharma et al., 2003; Obradovic et al., 1992). However, these fungicides are expensive, hazardous to human beings, animals and plants. Moreover, protectant fungicides are less effective (Zitter et al., 1996 and Chaban et al., 1993). Hence, host resistance is an important alternative to minimize crop losses from *P. cubensis.* Some of the varieties have been found resistant, some tolerant while some susceptible to *P. cubensis* (Wehner and Shetty, 1997 and Zinati et al., 1987). In order to reduce the yield losses, it is essential to thoroughly test the resistance of locally available germplasms against *P. cubensis* and to pinpoint resistant or tolerant varieties.

The present study was carried out to evaluate the distribution of downy mildew of cucumber in district Nowshera, to evaluate cucumber cultivars for resistance to different isolates of *P. cubensis* and to assess the losses in yield components under artificial epiphytotic conditions.

2. Materials and methods

This pot experiment was conducted at the Department of Plant Pathology, Khyber Pakhtunkhwa Agricultural University, Peshawar during 2011 growing season of cucumber crop.

2.1. Severity of cucumber downy mildew in Nowshera

The survey was conducted in the cucumber growing regions to find out the severity of cucumber downy mildew in District Nowshera. Four locations (Tarujabba, Akora khattak, Peersabak and Jhangeera) were selected. Disease severities were assessed by

using the key (Table 1) ofJenkins and Wehner(1983). Disease severity was recorded in four fields in each location. Data on downy mildew severity was taken from four spots in each field. In each field, one meter square spot was selected and by visual observation and using the key, the data on cucumber downy mildew were recorded.

Table 1. Jenkins and Wehner (1983) disease severity key for downy mildew of cucumber.

Disease Severity Rating	Disease Severity Description
0	No foliar symptoms
1-2	Trace, 3-6 % of leaf area infected
3-4	Slight, 7-25 % of leaf area infected
5-6	Moderate, 26-75 % of leaf area infected
7-8	Advance, 76-94 % of leaf area infected
9	Plant dead, 97 % or more of leaf area infected

2.2. Pot experiment

In In the laboratory, infected leaves collected from four locations (Tarujabba, Peersabak, Akora khattak, Jhangeera) were soaked in sterilized distilled water and rubbed gently to dislodge sporangia. The sporangia concentration was determined with the help of a haemocytometer. The suspension was adjusted to $5x10^4$ sporangia/ml using sterilized distilled water (Vara et al., 1982). Nursery of five cucumber varieties (Desi, Long green, F_1 Hybrid, Dollar F_1 and Khyber) was raised in a screen house. A pot experiment was designed using 2 factors Completely Randomized (CR) design with three replications. There was a total of 25 treatments in each replication i.e. four isolates and one untreated check and five varieties. A total of 75 pots of uniform diameter (20cm) were selected. Then, farm yard manure (one-year-old), silt and clay were thoroughly mixed in the ratio of 1:1:1 (v/v). These 75 pots were filled with the medium and watered before transplantation. Cucumber seedlings at the 2 to 3-leaf stage were carefully uprooted and washed. The roots were inoculated by dipping in the spore suspension (5×10^4 sporangia/ ml) of *Pseudoperonospora cubensis* isolates as described by Vara et al., (1982) and transplanted into the pots. Pots were regularly checked and watered as required. Data were recorded on the following parameters;

2.3 Disease Severity (%)

Data on disease severity was recorded four times at an interval of ten days. The first data were recorded after ten days of inoculation according to the disease severity scale proposed by Jenkins and Wehner (1983).

2.3. Number of vines per plant

Data were recorded on the number of vines per plant for each variety. This was calculated before the senescence of the crop.

2.4. Vine Length (cm)

The length of the vines was measured for each treatment. This was done before the senescence of the crop.

2.5. Number of fruits per plant

Data on the number of fruits per plant were recorded. This was recorded by totaling the number of fruits in all picking.

2.6. Fruit yield (gm) per plant

Data on fruit yield were taken for all treatments in each replication. As this crop is

harvested in picking, total yield was calculated by adding all selections. All the recorded data were pooled for statistical analysis using F-test and means were separated by the Least Significant Difference (LSD) test (Dana, 2001).

2.7. Statistical analysis

Analyses were carried and the significant means for various traits were separated with the application of LSD test.

3. Results

3.1. Severity (%) of cucumber downy mildew in Nowshera

Data presented in Table 2 indicated significant differences ($p< 0.05$) of downy mildew severity among four locations (Peersabak, Jhangeera, Tarujabba and Akora Khattak). Maximum (54.3 %) disease severity was recorded in Jhangeera followed by Akora khattak (48.2 %). Minimum (19.7 %) was recorded in Peersabak. In five field highest (47.4 %) disease severity was found in field five and the lowest (22.6%) in field 2. Interaction of the locations and fields were also significantly different in downy mildew severity. In Peersabak, Jhangeera, Tarujabba, and Akora Khattak, the highest percentage of downy mildew was recorded in F_5 (76.0%), F_4 (83.0%), F_3 (44.5%), F_2 (39.5%) and F_1 (82.0%), respectively. While this was 12.5 (F_1), 4.8 (F_2), 15.8 (F_3), 17.3 (F_4) and 32.3% (F_5), respectively in the said locations (minimum).]

3.2. Pot experiment

3.2.1. Disease severity (%)

Data recorded after ten days of inoculation of cucumber cultivars with different isolates showed significant differences in percent disease severity (Table 3). This was 2.7 to 2.9 % in different cultivars.

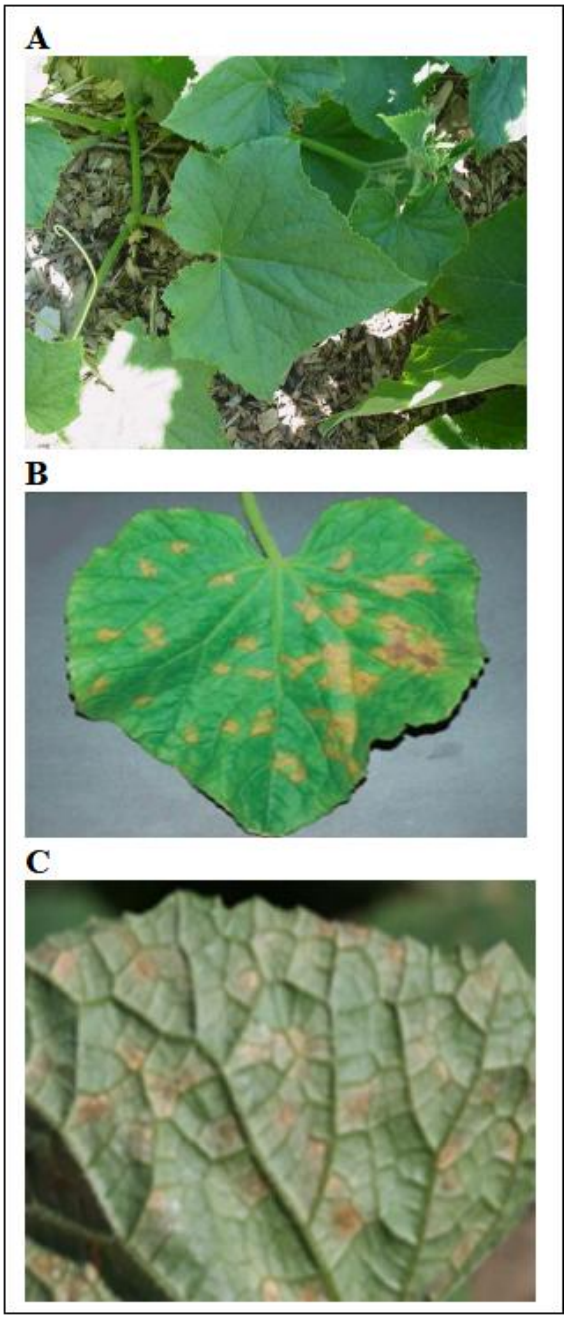

Figure 1. Symptoms of *Pseudoperonospora cubensis* on cucumber leaves. (A) Cucumber Leaf (Healthy), (B) Infected leaf, (C) Infected leaf.

The virulence of different isolates was 3.5 to 3.7 % with the highest of Peersabak isolate. However, the untreated check had no disease. Response of the cultivars to different isolates was also different. There was no disease on the untreated check. The cultivars responded 3.3-4.0, 3.3-3.7, 3.3-3.7 and 3.3- 3.7 % to different isolates (I_1, I_2, I_3 & I_4), respectively (Figure 1 & 2).

Disease severity data recorded after twenty days of inoculation of cucumber cultivars showed significant differences (Table 4) The down mildew severity on cultivars were 6.2 to 6.5%. The virulence of *P. cubensis* isolates on different cultivars was 7.4 to 7.9%. The cultivars which were not inoculated having 1.0% disease severity. The interaction of cultivars and isolates also had significant differences among themselves.

These were 1.0-8.3, 1.0-8.0, 1.0-7.7, 1.0-7.7 and 1.0-8.0% disease severity on Desi , Long green, F_1 Hybrid, Dollar F_1 and Khyber, respectively. The effect of different isolates (I_1, I_2, I_3& I_4) on cultivars were 7.3-7.7, 7.3-7.7, 7.7-8.0 and 7.7-8.3%, respectively.

Data on percent disease severity after 30 days of inoculation showed significant differences among the cultivars and the isolates (Table 5). Among the various isolates (Tarujabba, Peersabak, Akora Khattak and Jhangeera), the least (2.1%) disease severity was in control followed by Tarujabba (24.5%), Peersabak (25.1%), Akora khattak (25.1%) and Jhangeera (25.3%).

The various cucumber cultivars tested for disease severity (%) to different isolates differed significantly from each other. Cultivars Long green (22.5%), Khyber (22.4%), and Desi (22.0%) respectively gave no significant differences in disease severity indicating that they are equally susceptible to the disease. The least disease severity was recorded in F_1 Hybrid (17.4%) and Dollar F_1 (17.7%). Likewise, significant differences in disease severity (%) were seen as a result of interaction between different cultivars and isolates. Although disease severity was observed in all the combinations however, differences were significant. Variety Long green and Khyber showed the highest (26.7%) disease severity to isolate Tarujabba. Desi variety showed 26.0% disease severity. The least disease severity was recorded in Dollar F_1 (21.3%) and F_1 Hybrid (21.7%). On the other hand the highest disease severity was recorded in Long green (28.0%) followed by Khyber (27.3%) and Desi (26.7%) subjected to Peersabak isolate. F_1 Hybrid (21.1%) and Dollar F_1 (22.3%) showed the minimum disease severity. The varieties Long green and Desi showed the highest (27.7%) disease severity followed by Khyber (27.3%) in response to isolate Akora Khattak. while the lowest disease severity in F_1 Hybrid (21.3%) and Dollar F_1 (21.7%) of Peersabak and Tarujabba isolates. Variety Long green and Khyber showed the highest (28.3%) disease severity against the isolate Jhangeera. However, Desi showed 27.7%. F_1 Hybrid and Dollar F_1 gave the same and minimum disease severity (21.0%).

Data (Table 6) recorded after 40 days of inoculation showing significant differences ($p<0.05$) in disease severity. Among the 4 isolates, the highest disease severity was in a Jhangeera (60.5%) and the minimum disease severity in control (5.6%) followed by isolate Taru jabba (58.9%), while isolate Peersabak (59.7%) and isolate Akora Khattak (60.1%)

showed no significant differences in disease severity. The least disease severity (29.1%) and (29.6%) in F_1 hybrid and Dollar $F_{1,,}$ respectively. The highest disease severity (63.5%) was in Khyber. No significant differences were found in Desi (61.4%) and Long green (61.3%), respectively. The interaction was also significant (p<o.o5). There were no significant differences among varieties (Desi, Long green, F_1 Hybrid, Dollar F_1 and Khyber) in control. Least disease severity (5.0%) was in Long green and F_1 Hybrid and highest disease severity in Khyber (6.7%) in control. The highest disease severity in Khyber (77.0%) followed by Desi (75.0%) and Long green (74.3%) to isolate Tarujabba. While least disease severity was in F_1 Hybrid (33.7%) and Dollar F_1 (34.7%). They showed no significant differences. Variety Khyber (76.7%) showed highest disease severity to isolate Peersabak. There were no significant differences in Desi (75.3%) and Long green (76.0%). There were also non-significant differences in F_1 hybrid and Dollar F_1 (35.3%) showed least disease severity (%). Variety Khyber showed highest (79.3%) disease severity to isolate Akora Khattak. There were non-significant differences in variety Desi and Long green (75.0%). Least disease severity was in variety F_1 Hybrid (35.0%) and Dollar F_1 (36.0%). Disease severity was high in Khyber (77.7%) to isolate Jhangeera followed by Desi (76.3%) and Long green (76.0%). Non-significant differences in F_1 Hybrid (36.7%) and Dollar F_1 (36.0%) having least disease severity.

3.2.2. Number of vines

Data in Table 7 indicated main effect of isolates exhibited no significant effect on no of vines. Mean number of vines ranged from 1.9 to 2 .1 in 4 isolates. Maximum (2.8) no of vines recorded in control. However, in main effect of varieties F_1 Hybrid and Dollar F_1 had non-significant and maximum (2.7) no of vines. No of vines was minimum (1.7) in Long green and Khyber. The interaction was significant. In control, the maximum number of vines were in Dollar F_1 (3.7) and minimum in Khyber (2.3), Desi (2.3) and Long green (2.3), respectively. Variety Dollar F_1 (2.7) produced maximum number of vines to isolate Tarujabba. While it was minimum (1.7) in Long green and Khyber. F_1 Hybrid and Dollar F_1 produced maximum (2.3) number of vines when infected with isolate 2 (Peersabak). While it was minimum (1.7) in Desi , Long green and Khyber. There were non significant difference in F_1 Hybrid and Dollar F_1 showed maximum (2.7) number of vines to isolate 3 (Akora Khattak) and minimum in Khyber (1.3) to isolate 3 (Akora Khattak). Number of vines were maximum in variety F_1 Hybrid (2.7) to isolate 4 (Jhangeera) and variety Long green (1.3) showed minimum to that isolate. The number of vines of non inoculated cultivars were 2.3 to 3.7 with highest (3.7) in Dollar F_1.

Table 2. Severity (%) of *Pseudoperonospora cubensis,* the cause of cucumber downy mildew in Nowshera.

Locations	Fields (F)					Mean
	F_1	F_2	F_3	F_4	F_5	
Peersabak	16.5g	15.8g	16.5g	17.3g	32.3g	19.7c
Jhangeera	60.8ef	39.5b	44.5cde	83.0c	43.8a	54.3a
Tarujabba	12.5gh	4.8h	15.8e	33.8ef	37.5cdef	20.9cdef
Akora khattak	82.0a	30.3f	16.3g	36.3def	76.0a	48.2b
Mean	42.9	22.6c	23.3c	42.6b	47.4a	35.7

LSD value for location (L) = 3.6, LSD value for field (F) = 4.0, LSD value for F X L = 8.0
CV (%) = 15.9

Table 3. Effect of different isolates of *Pseudoperonospora cubensis* on different cucumber varieties after ten days of inoculation.

Isolates	Varieties					Mean
	Desi	Long green	F_1 Hybrid	Dollar F_1	Khyber	
Control (I_0)	0.0b	0.0b	0.0b	0.0b	0.0b	0.0b
Tarujabba (I_1)	3.7a	3.3a	3.7a	3.3a	3.7 a	3.5a
Peersabak (I_2)	4.0a	3.7a	3.7a	3.3a	3.7a	3.7a
Akora khattak (I_3)	3.3a	3.3a	3.3a	3.7a	3.7a	3.5a
Jhangeera (I_4)	3.7a	3.7a	3.7a	3.3a	3.3a	3.5a
Mean	2.9a	2.8a	2.9a	2.7a	2.9a	2.3

LSD value for isolates (I) = 0.4; LSD value for varieties (V) = 0.4; LSD value for I x V = 0.0
CV (%) = 19.1 * Means followed by different letter(s) are significantly different from one another at 5% level of significance.

Table 4. Effect of different isolates of *Pseudoperonospora cubensis* on different cucumber varieties after twenty days of inoculation.

Isolates	Varieties					Mean
	Desi	Long green	F_1 Hybrid	Dollar F_1	Khyber	
Control (I_0)	1.0 b	1.0b	1.0b	1.0b	1.0b	1.0b
Tarujabba (I_1)	7.7 a	7.3a	7.3a	7.3a	7.3a	7.4a
Peersabak (I_2)	7.3 a	7.7a	7.7a	7.7a	7.3a	7.5a
Akora khattak (I_3)	8.0 a	8.0a	7.7a	7.7a	7.7a	7.8a
Jhangeera (I_4)	8.3 a	7.7a	7.7a	7.7a	8.0a	7.9a
Mean	6.5 a	6.3a	6.3a	6.3a	6.3a	6.3

LSD value for isolates (I) = 0.7; LSD value for varieties (V) = 0.7; LSD value for I x V = 1.7
CV (%) = 16.0

Table 5. Effect of different isolates of *Pseudoperonospora cubensis* on different cucumber varieties after thirty days of inoculation.

Isolates	Varieties					Mean
	Desi	Long green	F_1 Hybrid	Dollar F_1	Khyber	
Control (I_0)	2.0d	2.0d	2.0d	2.0d	2.3d	2.1b
Tarujabba (I_1)	26.0b	26.7ab	21.7c	21.3c	26.7ab	24.5a
Peersabak (I_2)	26.7ab	28.0ab	21.0c	22.3c	27.3ab	25.1a
Akora khattak (I_3)	27.7ab	27.7ab	21.3c	21.7c	27.3ab	25.1a
Jhangeera (I_4)	27.7ab	28.3a	21.0c	21.0c	28.3a	25.3a
Mean	22.0a	22.5a	17.4b	17.7b	22.4a	20.4

LSD value for isolates (I) = 1.03; LSD value for varieties (V) = 1.03; LSD value for I x V = 2.3
CV (%) = 6.9 ; * Means followed by different letter(s) are significantly different from one another at 5% level of significance.

Table 6. Effect of different isolates of *Pseudoperonospora cubensis* on different cucumber varieties after forty days of inoculation.

Isolates	Varieties					Mean
	Desi	Long green	F_1 Hybrid	Dollar F_1	Khyber	
Control (I_0)	5.3e	5.0e	5.0e	6.0e	6.7e	5.6e
Tarujabba (I_1)	75.0bc	74.3c	33.7d	34.7d	77.0abc	58.9b
Peersabak (I_2)	75.3bc	76.0bc	35.3d	35.3d	76.7abc	59.7abc
Akora khattak (I_3)	75.0bc	75.0bc	35.0d	36.0d	79.3a	60.1ab
Jhangeera (I_4)	76.3abc	76.0bc	36.7d	36.0d	77.7ab	60.5a
Mean	61.4b	61.3b	29.1c	29.6c	63.5a	48.9

LSD value for isolates (I) = 1.5; LSD value for varieties (V) = 1.5; LSD value for I x V = 3.3
CV (%) = 4.1

Table 7. Effect of different isolates of *Pseudoperonospora cubensis* on number of vines of different cucumber cultivars.

Isolates	Varieties					Mean
	Desi	Long green	F_1 Hybrid	Dollar F_1	Khyber	
Control (I_0)	2.3cd	2.3cd	3.3ab	3.7a	2.3cd	2.8a
Tarujabba (I_1)	2.0cde	1.7de	2.3cd	2.7bc	1.7de	2.1b
Peersabak (I_2)	1.7de	1.7de	2.3cd	2.3cd	1.7de	1.9b
Akora khattak (I_3)	1.7de	1.7de	2.7bc	2.7bc	1.3e	2.0b
Jhangeera (I_4)	1.7de	1.3e	2.7bc	2.3cd	1.7de	1.9b
Mean	1.9b	1.7b	2.7a	2.7a	1.7b	2.1

LSD value for isolates (I) = 0.4; LSD value for varieties (V) = 0.4; LSD value for I x V = 0.98
CV (%) = 27.9 * Means followed by different letter(s) are significantly different from one another at 5% level of significance.

Table 8. Effect of different isolates of *Pseudoperonospora cubensis* on vine length (cm) of different cucumber cultivars.

Isolates	Varieties					Mean
	Desi	Long green	F_1 Hybrid	Dollar F_1	Khyber	
Control (I_0)	129.3a	113.3b	97.0cde	102.7c	101.7cd	108.8a
Tarujabba (I_1)	87.7fgh	87.0fgh	89.0efgh	86.7fgh	88.0fgh	87.7b
Peersabak (I_2)	93.7defg	88.0fgh	91.0efgh	84.7h	85.7gh	88.6b
Akora khattak (I_3)	94.0c-g	85.7gh	89.0efgh	88.0fgh	87.0fgh	88.7b
Jhangeera (I_4)	95.3cdef	88.7efgh	89.3efgh	87.7fgh	88.7efgh	89.9b
Mean	100.0a	92.5b	91.1 b	89.9b	90.2b	92.7

LSD value for isolates (I) = 3.98; LSD value for varieties (V) = 3.98; LSD value for I x V = 8.9
CV (%) = 5.9

Table 9. Effect of different isolates of *Pseudoperonospora cubensis* on number of fruits per plants of different cucumber cultivars.

Isolates	Varieties					Mean
	Desi	Long green	F_1 Hybrid	Dollar F_1	Khyber	
Control (I_0)	5.7de	6.0de	8.3a	7.7ab	5.3ef	6.6a
Tarujabba (I_1)	3.7gh	3.3gh	7.3abc	6.7bcd	4.3fg	5.1b
Peersabak (I_2)	3.3gh	3.3gh	7.3abc	6.3cde	3.7gh	4.8b
Akora khattak (I_3)	3.7gh	3.3gh	7.7ab	6.3cde	3.7gh	4.9b
Jhangeera (I_4)	3.0h	3.3gh	7.3abc	6.3cde	3.3gh	4.7b
Mean	3.9c	3.9c	7.6a	6.7b	4.1c	5.2

LSD value for isolates (I) = 0.5; LSD value for varieties (V) = 0.5; LSD value for I x V = 1.02
CV (%) = 11.9 * Means followed by different letter(s) are significantly different from one another at 5% level of significance.

Table 10. Effect of different isolates of *Pseudoperonospora cubensis* on yield per plant (gm) of different cucumber cultivars.

Isolates	Varieties					Mean
	Desi	Long green	F_1 Hybrid	Dollar F_1	Khyber	
Control (I_0)	606.7gh	626.7fgh	1000.0a	839.3b	563.3h	727.2a*
Tarujabba (I_1)	381.7ij	381.7ij	791.7bcd	728.3cde	441.7i	545.0b
Peersabak (I_2)	345.3j	384.3ij	806.3bc	693.3efg	382.0id	522.3b
Akora khattak (I_3)	376.3ij	380.0ij	800.0bcd	711.7def	388.0ij	531.2b
Jhangeera (I_4)	313.3j	377.3ij	801.7bcd	681.7efg	348.7ij	504.5b
Mean	404.7c	430.0 c	839.9a	730.9b	424.7c	566.0

LSD value for isolates (I) = 42.1; LSD value for varieties (V) = 42.1; LSD value for I x V = 94.2
CV (%) = 10.2 * Means followed by different letter(s) are significantly different from one another at 5% level of significance.

3.2.3. Vine length (cm)

Non significant differences ($P > 0.05$) were observed among various isolates (Table 8) . The highest (89.9 cm) in isolate 4 (Akora Khattak) while plants exhibited the least vine length (87.7 cm) in isolate 1 (Tarujabba). Vine length of five cultivars were 89.9-100.0 cm with highest (100 cm) in Desi and lowest (89.9 cm) in Dollar F_1.

The interaction was also significant and gave the differences in vine length of test cultivars under various isolates. F_1 Hybrid gained the highest (89.0 cm) vine length to isolate I_1 (Tarujabba). The vine length of Desi (87.7 cm), Long green (87.0 cm), Khyber (88.0 cm), Dollar F_1 (86.7 cm) and F_1 Hybrid (89.0 cm) were non significant among themselves. Likewise, the highest value of vinelength was obtained in Desi (93.7cm) to isolate 2 (Peersabak) followed by F_1 hybrid (91.0 cm). While it was least (84.7cm) in Dollar F_1. Desi (94.0 cm) showed the highest vine length to isolate 3 (Akora Khattak) followed by F_1 Hybrid (98.0cm), while the least vine length in Long green (85.7cm) . Moreover, the plants inoculated with I_4 (Jhangeera) produced vine length by 87.7 to 95.3 cm with highest (95.3 cm) in cultivar Desi. The vine length of non inoculated cultivars were 97.0 -129.3 cm with highest (129.3 cm) of cultivar Desi.

3.2.4. Number of fruits per plant

Significant difference ($P<0.05$) were observed among main effects in various cultivars (Table 9). Highest (7.6) number of fruits per plant was observed in F_1 Hybrid followed by Dollar F_1 (6.7). Plants exhibited the least mean number of fruits (3.9) in cultivars Desi and Long green. There were non-significant differences in various isolates. The highest (6.6) value of number of fruits per plant were in control followed by (5.1) isolate I_1 (Tarujabba). The interaction was significant and gave differences in number of fruits per plants. Among the cultivars, the highest number of fruits per plant in control of F_1 Hybrid was 8.3 followed by Dollar F_1 (7.7). While it was minimum in Khyber (5.3) in isolate I_1 (Tarujabba). Number of fruits per plant in Desi and Long green were 3.3 for isolate 2 (Peersabak). F_1 Hybrid showed highest (7.3) number of fruits per plant followed by Dollar F_1 (6.3). No significant differences between Desi (3.3) and Long green (3.3) were shown. Maximum number of fruits per plant were produced by F_1 Hybrid (7.7) followed by Dollar F_1 (6.3) to isolate 3 (Akora Khattak) and minimum by Long green (3.3). Likewise isolate 4 (Jhangeera) showed the same results that highest (7.3) number of fruits per plant were of F_1 Hybrid plants followed by Dollar F_1 (6.3) and minimum in Desi (3.0).

3.2.5. Yield per plant (gm)

Data in Table 10 indicated significant differences occurred in yield per plant (gm) on various isolates. Highest yield (727.2 gm) was obtained in check plants. F_1 Hybrid gave maximum (1000.0 gm) yield per plant followed by Dollar F_1 (839.3 gm) while minimum yieldwas obtained in Khyber (563.3 gm). However, out of four isolates Tarujabba (I_1) gave the highest (545.0 gm) followed by isolate Peersabak (522.3 gm). Minimum (504.5 gm) yield was obtained in Jhangeera (I_4). On contrary significant differences ($p<0.05$) in yield per plant was recorded in various test cultivars. F_1 hybrid gave the highest (839.9 gm) yield per plant. It was

followed by Dollar F_1 (730.9 gm). Minimum was recorded in Desi (404.7 gm). Differences in yield were significant in interaction too. F_1 Hybrid gave the highest yield (791.7 gm), followed by Dollar F_1 (728.3 gm) to Tarujabba (I_1). Non significant differences were found in Desi (381.7gm) and Long green (381.7 gm) which were minimum. Likewise, highest yield (806.3 gm) were found in F_1 Hybrid followed by Dollar F_1 (693.3 gm) to Peersabak (I_2). Minimum yield was recorded in Desi (345.3 gm).

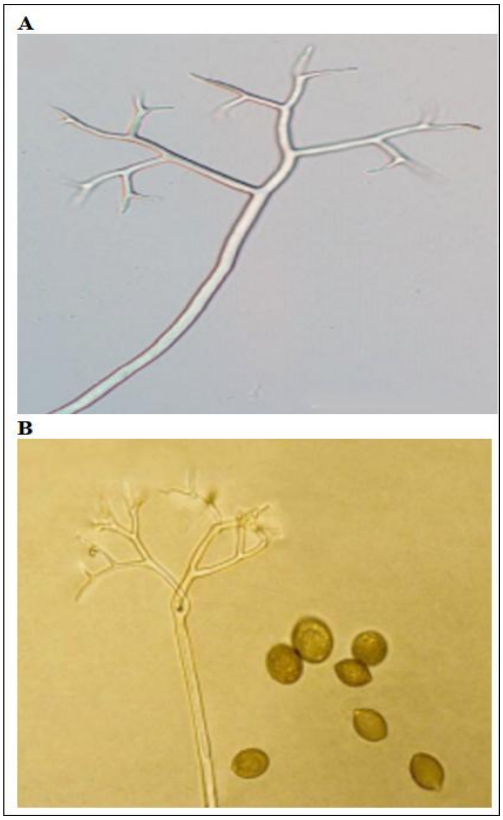

Figure 2. Structure of (A) Sporangia and (B)sporangiaphore of Pseudoperonospora cubensis.

Variety F_1 Hybrid gave highest (800.0 gm) followed by Dollar F_1 (711.7 gm) to Akora Khattak (I_3) and minimum was recorded in Desi. F_1 Hybrid and Dollar F_1 gave the highest yield (801.7 gm) and (681.7 gm) to isolate Jhangeera (I_4), respectively.

4. Discussion

Downy mildew has been observed to cause severe yield losses to cucumber in Khyber Pakhtunkhwa. The disease not only reduces the yield but also adversely affects the quality in the form of misshapen cucumber fruits. Such fruits fetch low price in the market. On the other hand, low yield are obtained when the photosynthetic area are badly damaged by the *Pseudoperonospora cubensis*. However, the rapid increase in fungicide prices, their less availability in the market and the ignorance of the farmers about their proper use or the use of non chemical methods have made downy mildew control more difficult. Keeping in view these points, this project research was aimed to investigate the variability among the different isolates for their virulence. The infestation of *P. cubensis* were highest in Jhangeera followed by Akora Khattak and lowest in Peersabak. Variability in disease severities were also found within the locations too. This might be due to virulence of the pathogen and favorable environmental conditions including sowing of susceptible varieties and monoculturing of the crop (Wehner and Sheity 1997, Nischit 2002 and Salati, 2010). In the present study, five cucumber cultivars (Desi, Long green, F_1 Hybrid, Dollar F1 and Khyber) being tested for their response to 4 isolates that were collected from different locations (Tarujabba, Peersabak, Akora Khattak and Jhangeera) from Nowshera District.

Responses of the different varieties were not much variable to different isolates of *Pseudoperonospora cubensis.* With the

passage of time, variability was disclosed by different varieties to those four isolates. After ten days and twenty days inoculation there were non significant differences, however at thirty days the cultivars Long green, Khyber and Desi showed maximum disease severity indicating that these cultivars were highly susceptible and minimum disease severity were found in F_1 Hybrid and Dollar F_1 that showed these cultivars were moderately resistant but not immune to *Pseudoperonospora cubensis*. It was also reported that F_1 Hybrid was considered to be less susceptible to downy mildew (*Pseudoperonospora cubensis*) of cucumber. After forty days of infection, there were significant differences among the isolates and cultivars. Among the cultivars, F_1 Hybrid and Dollar F_1 were moderately resistant and showed minimum disease severity. Khyber showed high susceptibility followed by Long green and Desi. Among the four isolates, Jhangeera (I_4) was more aggressive followed by Akora Khattak, Peersabak and Tarujabba. In control there was least disease severity.

Maximum number of vines was recorded in F_1 Hybrid and Dollar F_1 while minimum in Long green and Khyber which was due to high infestation of the disease as compared to the infestation of different isolates. The control plants produced the maximum number of vines due to less attack of the disease. Maximum number of fruits per plant was found in F_1 Hybrid followed by Dollar F_1 and minimum fruits were recorded in Desi and Long green among the four isolates. Maximum numbers of fruits were obtained from Tarujabba isolate which were not much aggressive. They also produced maximum yield per plant. The maximum vine length (cm) was recorded in Desi. Minimum vine length recorded in Dollar F_1 followed by Khyber. However there was no significant difference found in four isolates. Least vine length recorded in Tarujabba isolate (I_1) and maximum vine length recorded in Jhangeera isolates (I_4). *Pseudoperonospora cubensis* is responsible for low yield parameters. This reduction was reported up to 80% (Lebeda and Schwinn, 1994; Lebeda and Urban, 2007).

Fruit yield is an important criterion to check and compare the genetic potential of different cultivars. Results showed that yield per plant was statistically different among the cultivars. Maximum fruit yield produced by F_1 Hybrid followed by Dollar F_1. This was due to less disease severity which contribute towards the final yield. Minimum yield per plant were recorded in Desi followed by Khyber and Long green. Crisswell *et al* (2008) and Crisswell & Wehner (2008) also reported similar results. Mean ratings for downy mildew foliar resistance of cucumber accessions in the germplasm were studied in North Carolina too (Adam, 2010). Among the four isolates there were non significant differences. Maximum yield per plant was found in Tarujabba because they were not aggressive and minimum in Jhangeera. The interaction of isolates with different cucumber cultivars resulted the difference in yield and yield components cultivars F_1 Hybrid and Dollar F_1 showed best results for having less disease severity and high yield per plant. Akora Khattak (I_3) and Jhangeera (I_4) were highly aggressive and they reduced the yield per plant as compared to other isolates (Adam, 2010).

5. Conclusions

The mean cucumber downy mildew severities were 19.7 to 54.3% with highest (54.3%) in Jhangeera. Among the fields of different locations (interaction of locations and fields), it was 4.8 to 83.0%. Mean cucumber downy mildew severity was 58.9 to 60.5% with maximum (60.5%) by Jhangeera isolates after 40 days of inoculation. Mean severity of disease of different isolates was 29.1 to 63.5% with minimum on variety F1 Hybrid. The interaction of isolates and varieties revealed that it was 33.7 to 79.3% with minimum in F1 Hybrid. The overall performance of cultivars F1 Hybrid was best having less disease severity and highest yield and yield components than the other cultivars. Further systematic research for the hunt of the source of resistance against the cucumber downy mildew disease in different agro-ecological zones of Khyber Pakhtunkhwa is recommended.

Author contributions

A.R and H.K conceived the main idea of research and wrote the manuscript. F.R and M revised the manuscript and provided suggestions. In addition HK and AR assessed and analyzed the data, and performed data collection. All authors have read and agreed to the published version of the manuscript.

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Conflicts of interest

The authors declare no conflict of interest.

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